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FIRST QUARTERLY REPORT

FOR

ADDITIVE CONVERTER STUDIES

By

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Report No. 20-63

Contract No. AF 33(657)-10130

March, 1963

Prepared for

Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio

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FOREWORD

The work covered by this report was accomplished under Air Force Contract No. AF 33(657)-10130, but this report is being published and distributed prior to Air Force review. The publication of this report, therefore, does not constitute approval by the Air Force of the findings or conclusions contained herein. It is published for the exchange and stimulation of ideas.

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SUMMARY

This report outlines the background to and the progress of the first three months of the additive thermionic converter parametric investigation. The reasons for the expectation of better performance of the thermionic converter, due to the addition of electronegative atoms, are given. The designs used in the experimental verification of these expectations are shown. Background work and plans for the future are discussed.

CHAPTER 1

INTRODUCTION

The purpose of the investigations under this contract can be divided into two categories:

1. The quantitative determination of the effect onthermionic converter output, efficiency and surface emission characteristics due to the addition of fluorine, chlorine, and oxygen to the test chamber.
2. The possible corrosive effect on converter construction materials of these additives.

It is expected that the addition of the elements will materially increase the useful output and efficiency of the thermionic converter. It is also expected that the corrosive effects of these additives may be held to a minimum, such that the lifetime operation of the converter will not be unduly affected.

The first quarter has been devoted to the design and construction of the necessary test vehicles to accomplish the purpose of the program. These devices are complete as to design and manufacture of parts. Construction is nearly finished and is expected to be complete by the time this report is published.

Both of these devices use designs which are unique to this group. The devices have in the past demonstrated their structural integrity and usefulness in research work.

CHAPTER 2

PRINCIPLE OF OPERATION

The physical principles of thermionic energy conversion have been described in many papers, notably those by Rasor and Nottingham.[1]

Briefly, an emitter maintained at a high temperature boils off electrons which are received by a collector held at a lower temperature. Cesium vapor is injected into the interelectrode space; cesium ions produced on the emitter surface reduce the work function of the emitter and neutralize the electron space charge.

It has been found that optimum converter operation combines the requirements of low emitter work function with low cesium pressure.[2, 3] Furthermore, it is known that those metals having the higher bare work functions give the lower net work functions when covered with adsorbed cesium. This result is expressed by Figure 1, derived from the work of Rasor, Warner,[2] and Houston.[4] Here, ϕ_o is the bare work function, ϕ the work function with adsorbed cesium, and the cesium pressure is expressed by T_R the temperature of the cesium reservoir.

The problem, therefore, is to modify the bare work function of the electrodes by the adsorption of some material with a high electron affinity. Such an effect has been observed as far back as 1925 by Langmuir and Kingdon,[5] wherein it was noted that the work function of tungsten increased by 0.8 ev when covered by a monolayer of oxygen.

Fluorine especially, being the most electronegative of the atoms, is expected to give good results.

Specifically, the use of additives will allow greater flexibility in the choice of parameters for investigation. The program will attempt to obtain data over a wide range of characteristics with the purpose of making available a starting point from which investigations into the basic nature of additive effects may be initiated.

The work will be of the same type and nature as that described in Reference 3.

CHAPTER 3

DESIGN AND CONSTRUCTION

In order to be able to investigate the effect of additives on thermionic converter operation, the experimental vehicle must be provided with two separate reservoirs. The first contains the cesium; the second the additive. Each reservoir may be heated independently and the partial pressures of the constituents separately controlled to achieve the most advantageous emitter and collector coverage.

To maintain this independent control, the additive (at a higher temperature than the cesium) must be prevented from condensing too rapidly into the cesium reservoir. This is effected by making a small egress from the cesium reservoir into the body of the tube. This orifice was calculated to provide for a running time of five hundred hours before the floride would have to be distilled out and testing resumed. At the same time, this orifice is of sufficient size to permit a rapid efflux of pressure changes in the cesium reservoir into the diode chamber.

Figure 1 shows this orifice as part of the additive inclusion heater assembly. Other important parts of the additive converter shown in Figure 2 are:

1. Radiator
2. Emitter support and spacing assembly
3. Emitter
4. Collector
5. Leadthrough assembly
6. Heat flux measuring section
7. Adapter plate
8. Vapor inlet tube
9. Heater section
10. Additive inclusion heater assembly
11. Cooling coil
12. Additive reservoir
13. Cesium heater
14. Cesium reservoir.

Figure 3 shows the additive converter assembled. Figure 4 shows the essential components; from left to right they are:

1. Cesium inlet tube and heater
2. Additive inlet tube
3. Additive inclusion heater assembly
4. Heat flux measuring section and collector assembly
5. Emitter spacing assembly
6. Emitter support
7. Emitter
8. Radiator.

The emitter is polycrystalline rhenium. Rhenium combines the advantages of high bare work function, low vaporization rate, and chemical inertness. Note that provision is made for the heating of the collector by electron bombardment. This allows a better determination of the effect of back emission current on the operating characteristics of the diode. Past investigations have indicated that "activation" of the collector would be advantageous in an investigation of this nature.

CHAPTER 4

CORROSION VEHICLE

It is important to determine the chemical effects of the additives on the construction materials of a thermionic converter. In order to measure these effects, a corrosion test vehicle has been designed.

Figure 5 shows this design. The important components are:

1. Emitter backing plate
2. Emitter face
3. Collector
4. Emitter spacer
5. Leadthrough assembly
6. Diode supporting plate
7. Vapor inlet
8. Cooling strap
9. Additive orifice block
10. Cesium floride reservoir
11. Cesium reservoir.

This design is one whose characteristics are well known. It was thought best to use a diode about which the basic operating conditions and parameters were well determined. Thus, departures from normality due to additive inclusion may be quickly and easily recognized.

This diode and others similar to it will be put on life test. After a sufficient time they will be dismantled and the changes due to the additives carefully studied. Of particular interest will be granular corrosion, pitting and marking of the electrode surfaces, grain boundary changes, floride combinations with materials, and ceramic degeneration. All the commonly used converter materials will be analyzed. This information will give valuable insight into the conditions necessary for the construction of high reliability long-life thermionic diodes.

CHAPTER 5

PROGRESS TO DATE

Specific progress in these investigations includes the aforementioned designs of both the additive converter and the corrosion test vehicle. In addition to this, the machining of parts has been completed. Construction is proceeding rapidly. The additive converter is complete, the corrosion test vehicle will be complete by the time this report is published. Testing will commence very soon.

In order to be able to record correct temperature measurements during operation, a calibration relating observed temperature at the rear of the emitter to the temperature at the face of the emitter also was done. Figure 6 gives the results of this measurement.

CHAPTER 6

PLANS FOR NEXT QUARTER

The next quarter will see the completion of the experimental testing setup, outgassing, and charging of both the additive converter and the corrosion vehicle. Testing will commence. It is expected that testing will proceed at an accelerated rate.

Initial testing will be followed by a second series of outgassing and charging procedures in preparation for an additional test sequence.

REFERENCES

[1]Nottingham, W. B., "Thermionic Emission," Tech. Report 321, Massachusetts Institute of Technology;

Rasor, N.S., "Emission Physics of the Thermionic Energy Converter," Proc. IRE (December, 1962).

[2]Rasor, N.S. and Warner, C., "Correlation of Electron, Ion and Atom Emission Processes," AI-6799, Sect. B-2 (November, 1961).

[3]S.S. Kitrilakis, M. Meeker and N.S. Rasor, "Annual Technical Summary Report for the Thermionic Emitter Materials Research Program," Thermo Electron Engineering Corporation, TEE 4015-3 (1962).

[4]Houston, J.M., Bul. Am. Phys. Soc. 6, Ser. II, 358 (1961).

[5]Langmuir, I. and Kingdon, K.H., "Thermionic Effects Caused by Vapors of Alkali Metals," Proc. Roy. Soc. A, 107, 61 (1925).

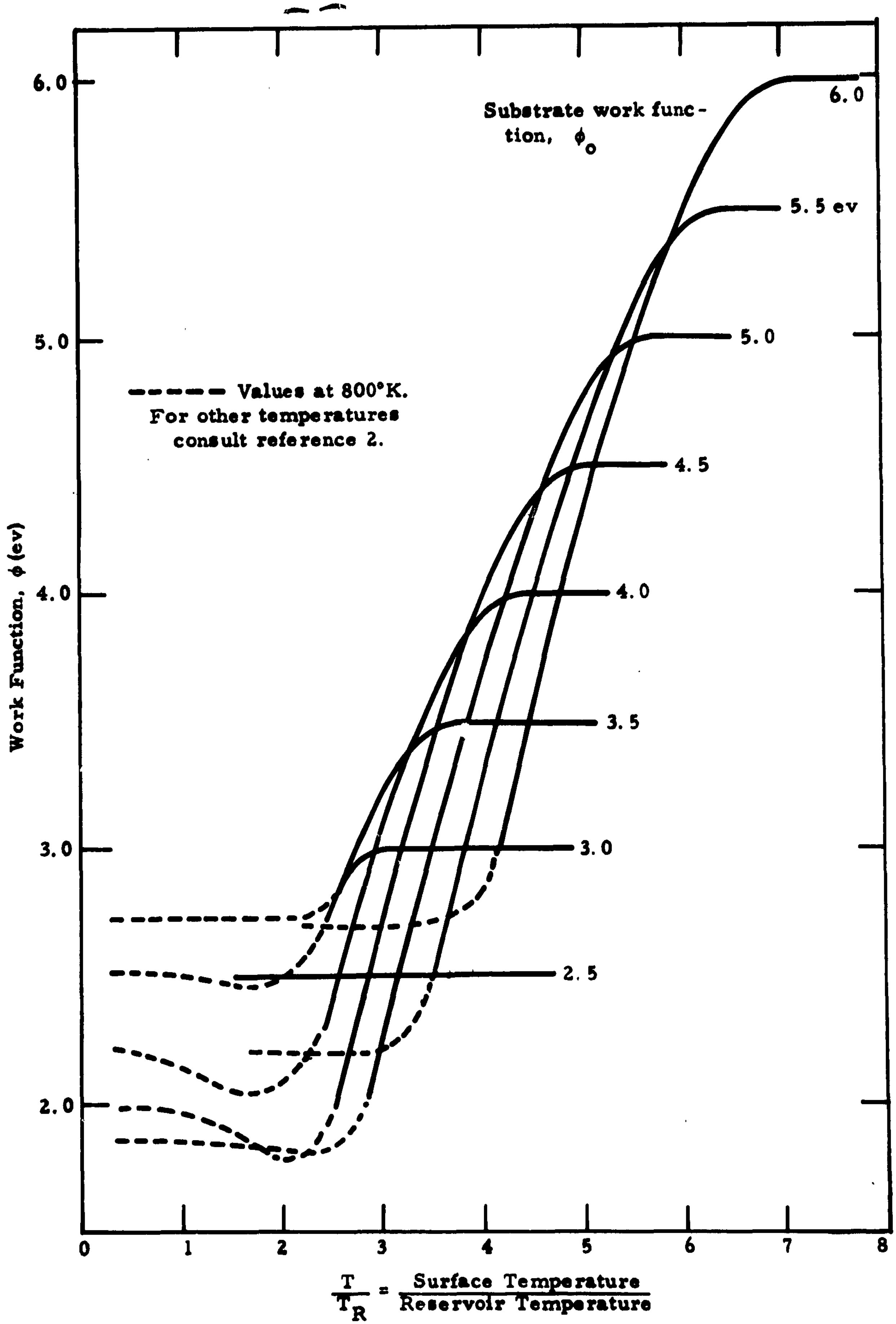
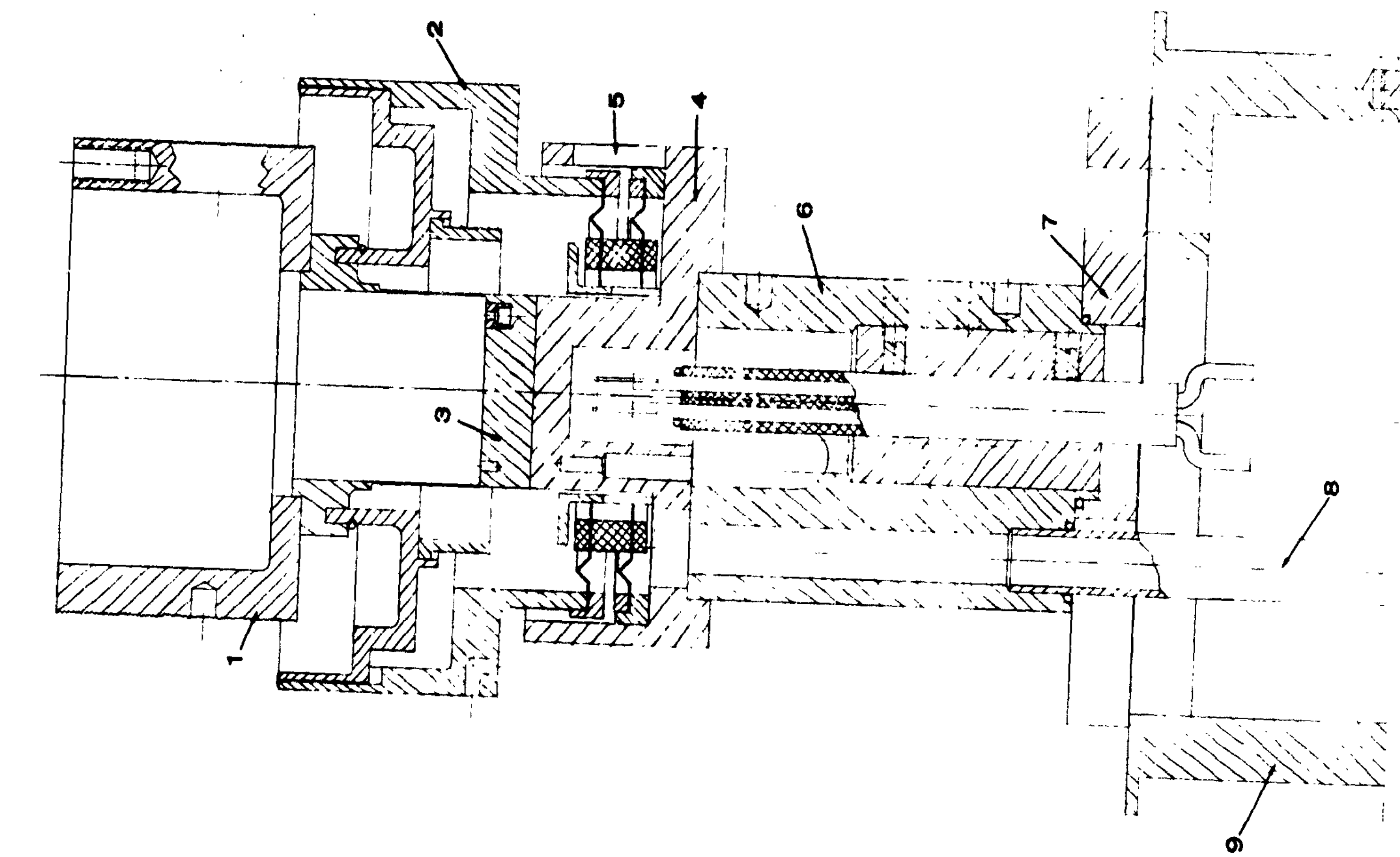


Figure 1. Work Function of Surface With Adsorbed Cesium



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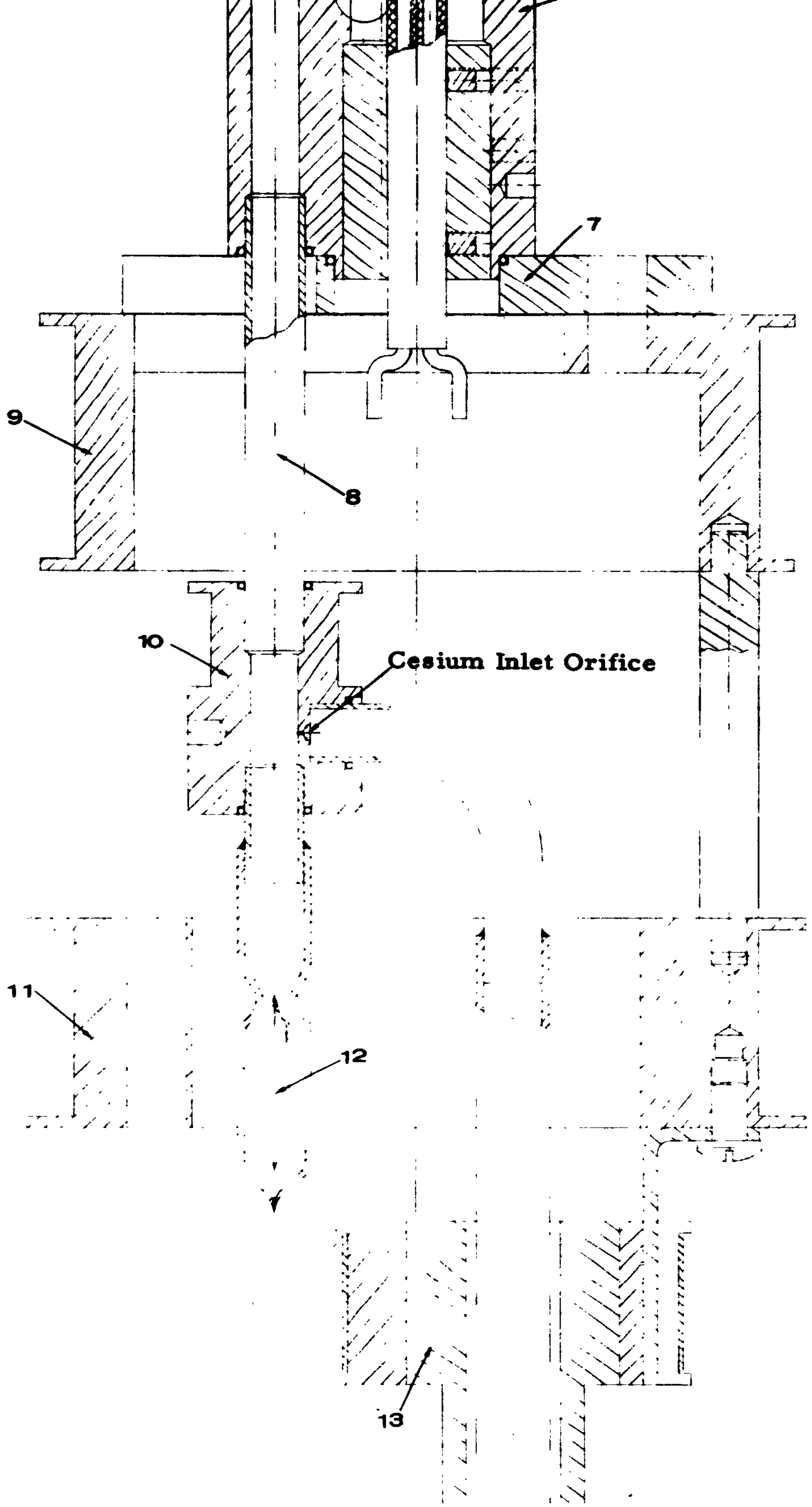

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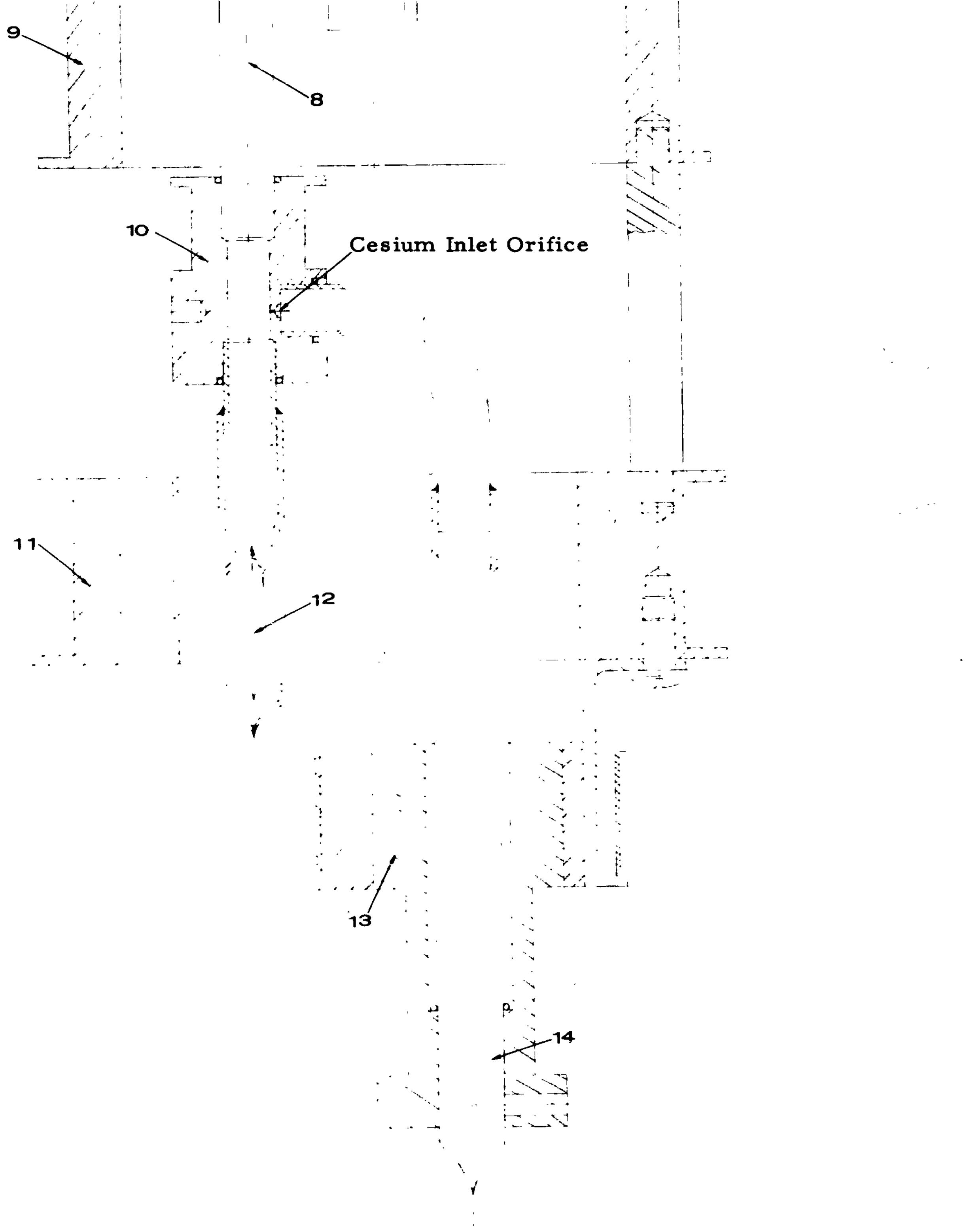

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Figure 2. Cross Section of Additive Thermionic Converter

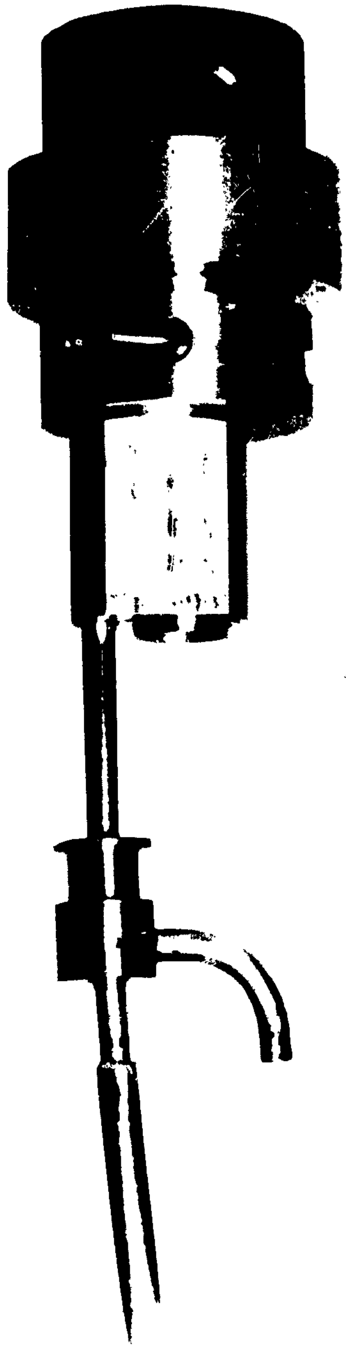

Figure 3. Photograph of Additive Thermionic Converter

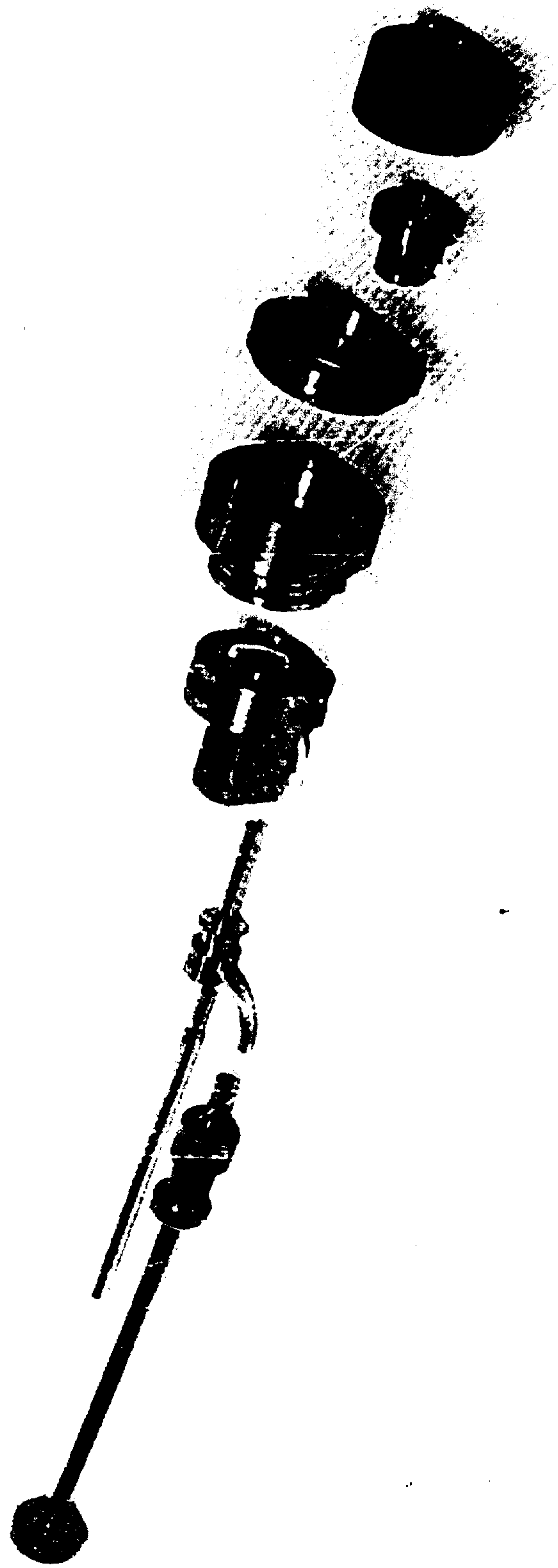

Figure 4. Photograph of Disassembled Additive Thermionic Converter

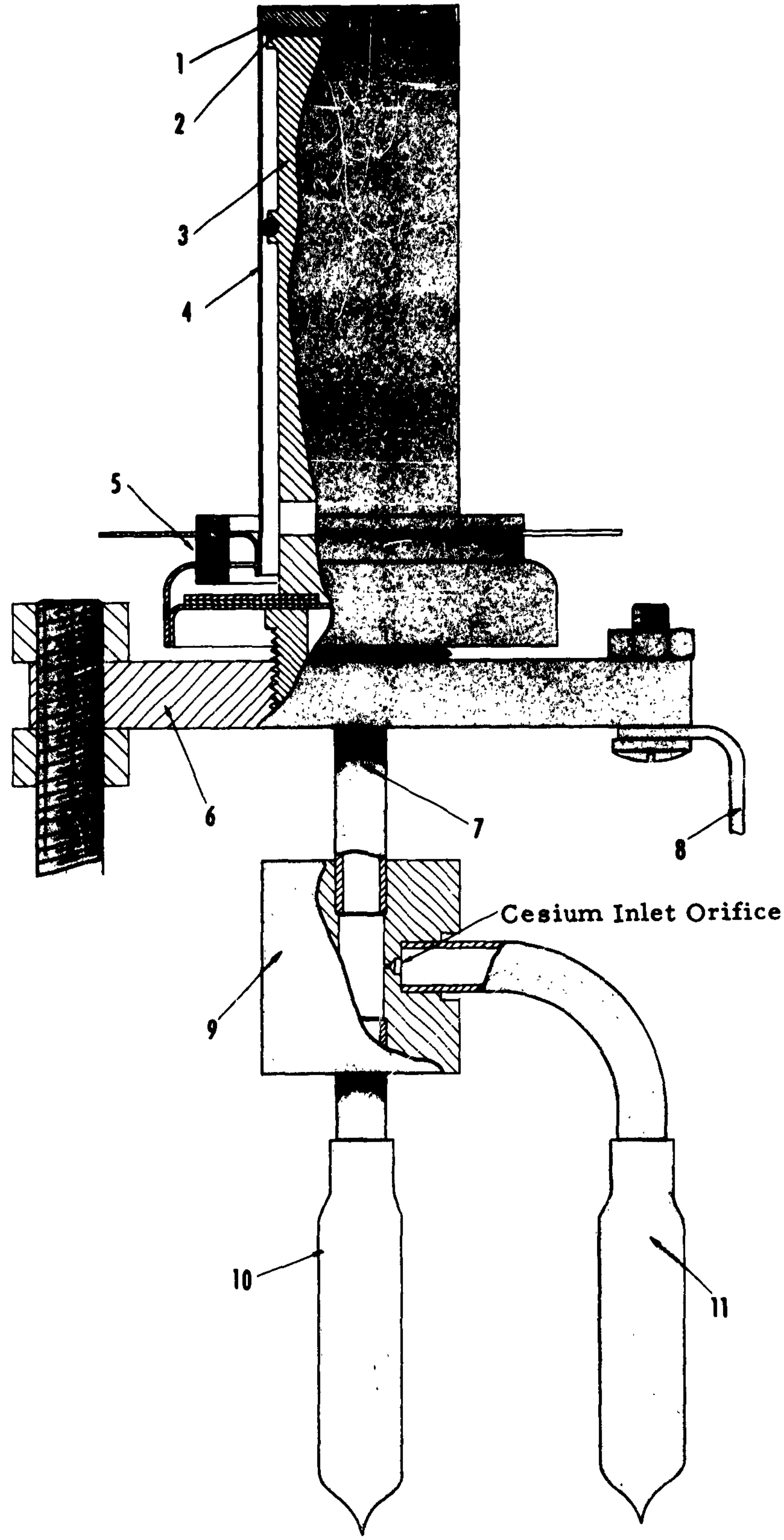

Figure 5. Corrosion Test Vehicle

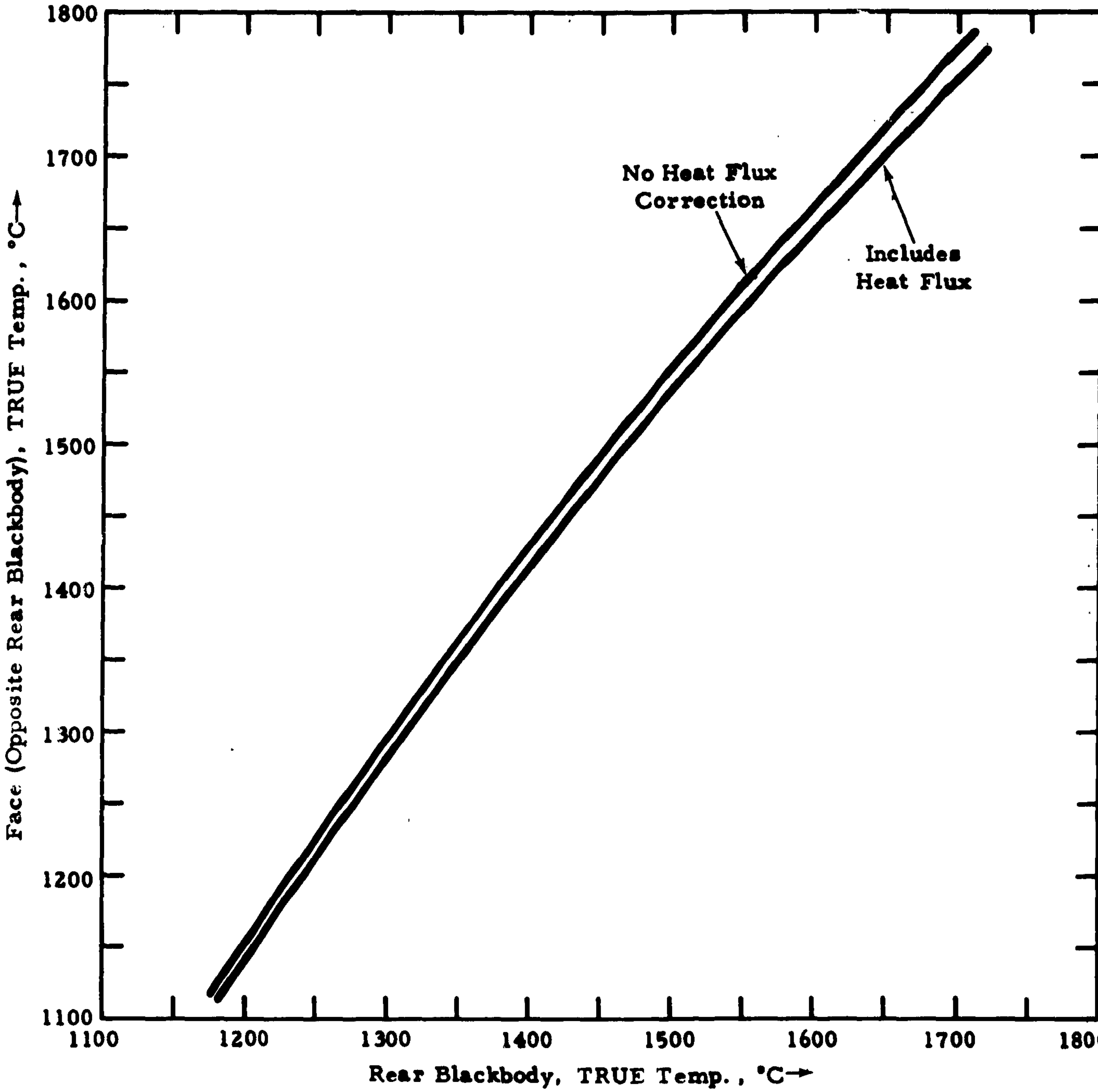

Figure 6. Emitter Calibration Curve

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